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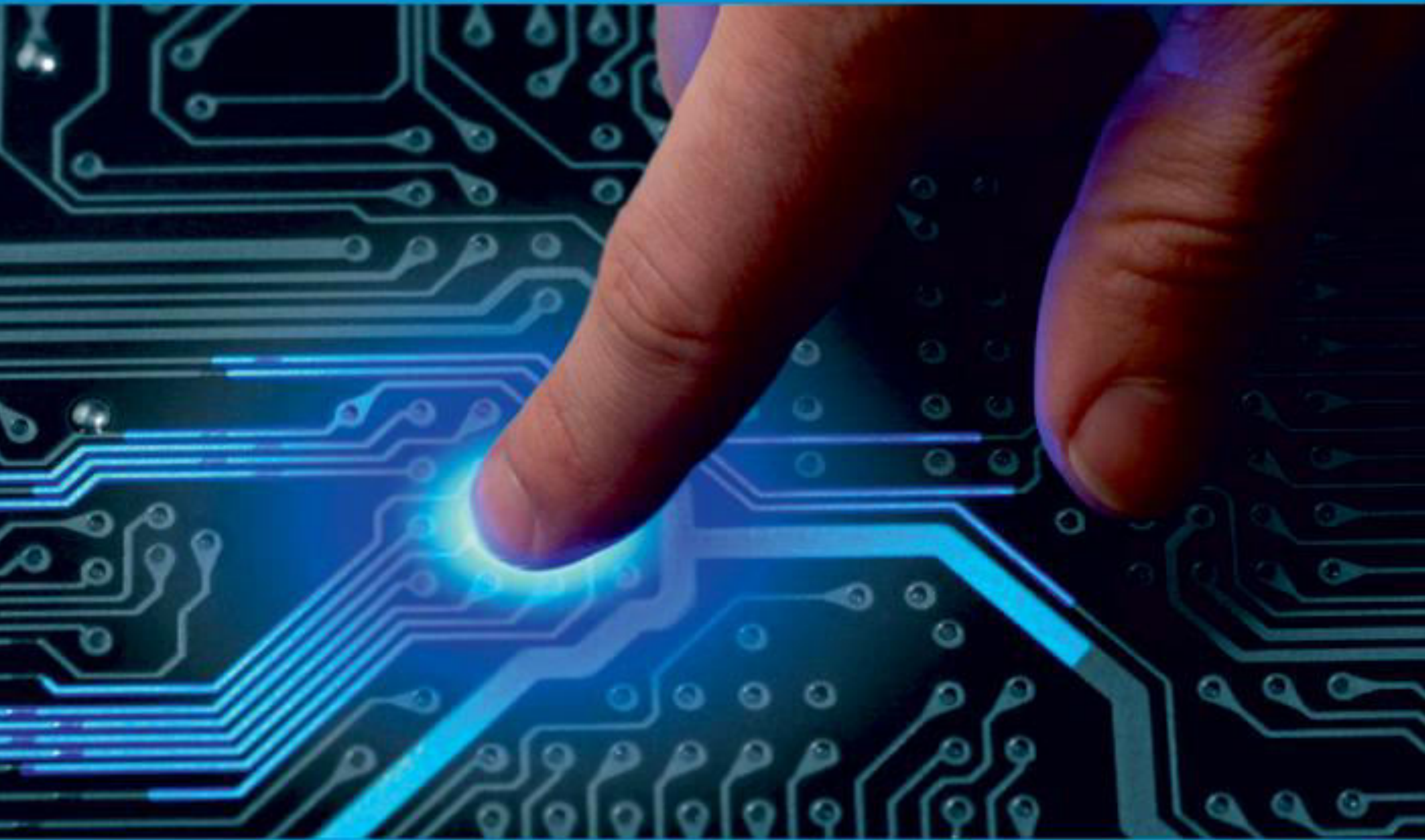

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Energy-Efficient Low-Energy Adaptive Clustering Hierarchy (LEACH) for Wireless Sensor Network

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ABSTRACT: Wireless sensor networks (WSNs), the Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm stands out as a promising approach to optimize energy consumption and extend network lifetime. This article explores into LEACH's capabilities and performance, with a focus on energy efficiency and network longevity. Through rigorous evaluation, we investigate how LEACH dynamically forms clusters, assigns cluster heads (CHs), and aggregates data from member nodes, distributing energy consumption evenly. Key metrics, including energy consumption, network lifetime, and data transmission reliability, are employed to assess LEACH's effectiveness in various WSN deployment scenarios. Furthermore, comparative analyses with alternative energy optimization algorithms shed light on LEACH's advantages and limitations. By validating our findings through simulations and real-world experiments, we offer practical insights for WSN design and deployment, aiding in informed decision-making. This article not only explores LEACH's potential but also paves the way for potential enhancements and adaptations, contributing to the on-going evolution of energy-efficient WSNs for diverse applications.

KEYWORDS: Energy Consumption, Wireless sensor networks, Low-Energy Adaptive Clustering Hierarchy, Cluster Heads,

I. INTRODUCTION

The routing process of SNs is a very complex and challenging owing to the fact that makes them different than other cellular networks routing protocols. Due to large number of tiny nodes deployment in a remote location, it is not easy to keep real time update of intrinsic attributes of network throughout of period. Somehow it increases the burden of overhead which keeps the updated information about network parameters impacting the bandwidth efficiency to large extent. Another point is that WSNs are deployed for monitoring of few events in a go. So basically, they are developed application specific and their attribute are also analysed based on the requirement of application. This restricts the routing protocols to be designed in wider purview of applications. Due to this, need arisen for continuously restructuring of already existing protocols according to the demand. For instance, the study of sleep and active nodes format in a protocol begins with strategic exploration of attributes adding required degree of exactness in a defined manner deriving relations to the required sporadic observation of environmental tasks. Finally, the location exactness or position becomes dominantly important to develop a sense of familiarity among sensor node in collecting information from all points. Extracting the benefits of global positioning system will not serve the purpose here for many tested reasons.

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Rising node densities play vital role for system execution in defined bounds. A good routing protocol should be scalable and dynamic in respect of network structure and topology. Therefore, protocols are bound to be flexible in modelling due to growing size of network and workload also. This work presents a mathematical model for evaluation and verification of routing protocol performance for scalability also. The computation of energy equations shows the appreciable performance for a greater number of nodes in same field dimension. Hence scalability becomes essential for routing protocol that relies on flooding of event generated queries. Decaying power and workload restrict the computation capabilities and sensing too; causing disruption to run cooperative transmission. However, routing protocol must be evaluated for growing number of participating nodes; is these changes can be tolerated without much degradation in performance metrics. Any network that is developed for scalability can be expanded with minimal loss of power and can be robust in functionality. Data packets must be transmitted without any record rise in overhead size; bringing bandwidth spectral efficiency in trade-offs. It is very challenging to provide a routing protocol with scalability benefit without compromise in performance. This generates many constraints while designing and modelling routing protocol. In recent times the significant focus has been given to scalability due to tremendous benefits associated with it. So far designed works shows restricted performances for large number of nodes due to pre-determined architecture and topology of network under monitoring. Of course, energy efficient routing is needed to establish reliable communication link between normal nodes and base station; and is significantly affected by nodes residual energy.

The limitation of routing protocols is due to restricted energy resources, less memory and limited data processing and handling capabilities. In recent years many solutions surfaced for scalability in different arena of WSNs. However, developing a robust protocol mainly depends on self-configured small size group in a network. These groups optimize the energy resources with adaptive and disseminated network management.

A new descendant is of hierarchy protocol is proposed here. Contribution of work can be summarized as follows;

- A model of many Layers has been proposed for energy conservation in low energy adaptive hierarchy protocol.
- The long-distance data transmission is aborted with the applications of many other clusters formation in intermediate levels.
- Multi hopping is used majorly for making communications.

II. LITERATURE SURVEY

Deng Zhixiang et al [11] has given a new idea for data fusion that is main logic behind CHs distribution in this routing mechanism. However, data fusionoriented methods rely on global energy optimization and reduced energy depletion at CH level. Hence energy is preserved in hop-by-hop transmission for entire network before forwarding data packets to sink. Wu et al [12] proposed a time driven clustering method in cooperation of relay nodes to devise mechanism for large networks. This mainly used in big farmland for monitoring purposes. It provides better connectivity throughout network with advantage for faster signal processing due to less complex network architecture.

Ahmed et al [13] proposed the chainbased clustering with relay nodes have added advantage for improves data delivery ratio and end to end connectivity for large network. It also works in cooperative manner for reliable communication. However very few routing methods are tested for scalability. Scalability has become an important property of SNs that describes its ability to get adaptive and system can be modified with varying demands of work load accordingly in fast evolving era of technology. For moderate to large system; there are many reasons that can affect the system model to high scale. Hence it is required to incorporate solutions to these reasons to remove bottlenecks in models. Generally, SNs have few common features of ad hoc network (MANET) different in small degrees e.g., limited mobility and less energy expenses; subjected to size of network and demand of type of services; for example, now a days data means multimedia data that requires entirely different approach and many of time restructuring of old protocols. Because of many discussed factors scalability has been an interpretative issue for long time.

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Rani Sandhya et al [14] described a secured scalable protocol with advantage of energy efficiency for clustering hierarchical network. It is an improved version of Leach. It uses significant relay nodes to facilitate the protection against network intrusion and enhances network lifespan. Antonopoulos et al [AAB08] presents that SNs routing algorithms and data compression and aggregation techniques are also employed to emphasize the resources optimization to allow network work well with restricted means. As SNs grows and strengthen nodes decays and require addition of more nodes to sustain the network for longer. His work addressed scalability of routing protocol and applies compression techniques to adhere to core object of network longevity with retaining work performance. It is demonstrated that as cluster structure sustain for more duration thus avoids running of cluster formation algorithm for a greater number of times; in turn saving resources. However supreme spatial distribution of nodes increase stability period means delaying death of nodes by high data compression methods employed during multi hop transmission.

Zuniga et al [15] describes that as the hardware of nodes is modified for rising network size then network can withstand for longer periods. It is always found that WSNs are need to be connected to outer internet world for real time monitoring in large scale technological inputs in many applications. Due to these varied reasons their feasibility is seek in IP enabled services with integration of SNs. It is also mentioned clearly that adaptive and scalable routing protocol is in demand for hybrid kind of networks thoroughly connected using local IP.

Nasiri et al [16] suggests that time synchronization is interpretative problem in SNs. It is proposed that a scalable light weight protocol with benefits of time synchronization is best for large scale networks. By implanting passive clustering and linear retro gradation makes this work withstand for longer duration with nominal burden of energy consumption. Creation of more overheads is also minimized and selective clustering is maintained. Moreover, it focuses more in calculating the time offset between node and cluster head to estimate the local time of transmission of very remote nodes. By this they refine power consumption heads considerably with improvement in accuracy and scalability advantage then other algorithms.

Ameesh Pandya, et al [17] provides that for networks that comprises thousands number of nodes with connectivity to outer physical world using global internet for wide range of applications; single nodes provided sensing, computation and signal processing can significantly render the possibility of cooperative task performing. Hence the constraints subjected to resources can be retreated as self-organizing and adaptive management for collective task completion in each epoch. It is notified here that under restricted scenario network can be regenerative due to scalability. The main strategy used here relies on permitted degradation for a defined level when a group of nodes are scalable; and govern by distributed phenomena.

III. LOW-ENERGY SECURE ROUTING FOR WIRELESS SENSOR NETWORKS BASED ON LEACH PROTOCOL

Implementing a low-energy secure routing approach for WSNs is crucial for prolonged network lifespan and data integrity. Leveraging the Low-Energy Adaptive Clustering Hierarchy protocol, this strategy focuses on minimizing energy consumption by employing efficient clustering. By integrating security measures within LEACH, the proposed method ensures data confidentiality and integrity during transmission. This approach enhances WSN resilience against potential threats without compromising energy efficiency, making it an ideal solution for resource-constrained sensor nodes. Through thoughtful adaptation of LEACH, the protocol not only optimizes energy utilization but also fortifies the network against security vulnerabilities.

This work is developed for hierarchical cluster-based method for application orientated scenarios. It depends on the fact that the energy dissipated for sending information to faraway place requires more energy than small distance (SDC) communications. It is assumed that there are nodes that work as associate instead of relying on single cluster for propagations to BS. Cluster formation is governed by RSSI of nodes; subsequently disseminating network administration.

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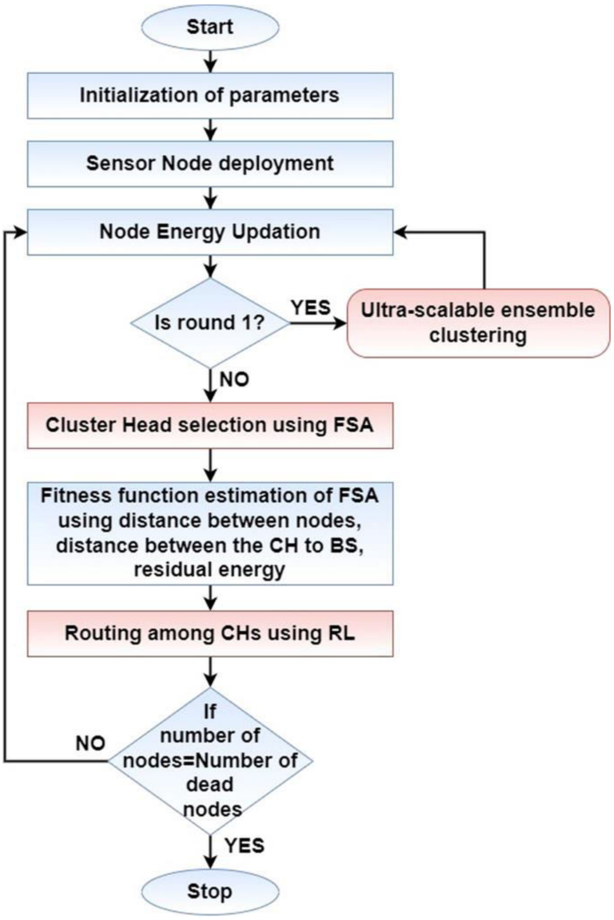

Fig 1: Flow chart of Model

However, task to handle traffic flow towards base station is distributed evenly among all associate node members. Complete operation works in two phases: cluster formation and transmission phase. In cluster formation phase the small set of nodes is formed with a leader to deliver centralized administration. Information is sensed and propagated in pre-defined slots to sink in data transmission phase. Best part of protocol is that it is self-organizing and very adaptive to the demands arisen in monitoring fields. At least once every head set member will attain a chance to become cluster head based on RSSI. To understand the information propagation through any RF communication link we require a radio frequency energy model. The radio energy model will help us in building up a mathematical model for data transfer and calculating energy used in bit transmission and bit manipulation operations.

Calculation of total energy of the two levels in network

Now calculating various energy components for level 2; for a different point of view; to assess the impact of multi hopping on energy model in present scenario; so, power utilized by an NCH is calculated as at level 2 can be calculated as equation given below; similar to previous case as it is represented by direct communication.

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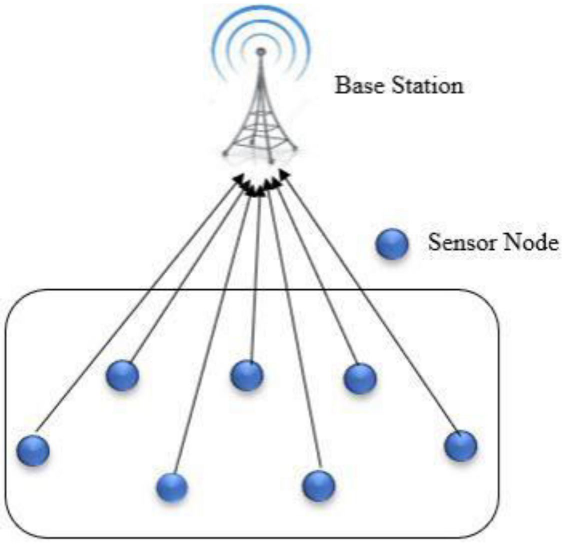

Fig 2: Direct Communication

Direct Communication It is assumed that for one cluster power used in aggregation and transmission of data to sink is calculated using energy model explained in section. It is drawn as:

$E_{level2\_cluster} = E_{CH} + Q * E_{non\_CH}$ ……………. .(1)

The power used by a non-CH (NCH) is given by Eq 2;

$E_{level2\_nonCH} = l * Ee + l * Es * d^2$ ……………. (2)

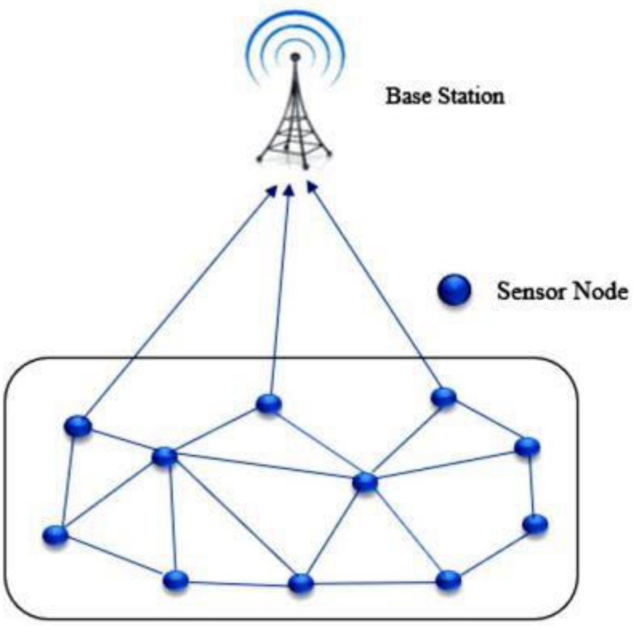

Fig 3: Multi Hop Communication

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Now calculating various energy components for level 2; for a different point of view; to assess the impact of multi hopping on energy model in present scenario; so, power utilized by an NCH is calculated as at level 2 can be calculated as equation given below; similar to previous case as it is represented by direct communication. Now energy dissipation at CH node is computed as;

$$E_{level2\_CH} = Q * l * E_e + l * E_l * d^4 + l * E_e + (Q + 1) * l * E_{DA} \qquad (3)$$

Hence the power used at level 2 in propagating the collected information to sink is estimated before exercising same radio energy model to compute the energy for level 1; start from NCH node; the power used by a CH is computed. Therefore, calculating total energy of network; found by summing all power elements covering total transmissions; occurring to deliver information to sink starting from sensing of event by nearest node.

IV. SIMULATION ANALYSIS BASED ON LEACH PROTOCOL

The performance metrics recorded during model synthesis using MATLAB 2023a. The first node dead and last node dead or complete network depletion is seen for improved Leach. The parameters clearly target the complete operational capacity along with energy conservation while maintaining QoS for the given network. The proposed model attains error free transmission using full operational capacity for 3650, 3266, 2890, 2860, 2510 in comparison of LEACH for 1278, 1280, 1272, 1310, 1345 for nearly 6500 rounds respectively. As seen in Fig the network life time has increased with maintaining connectivity for longer durations than earlier variant of LEACH.

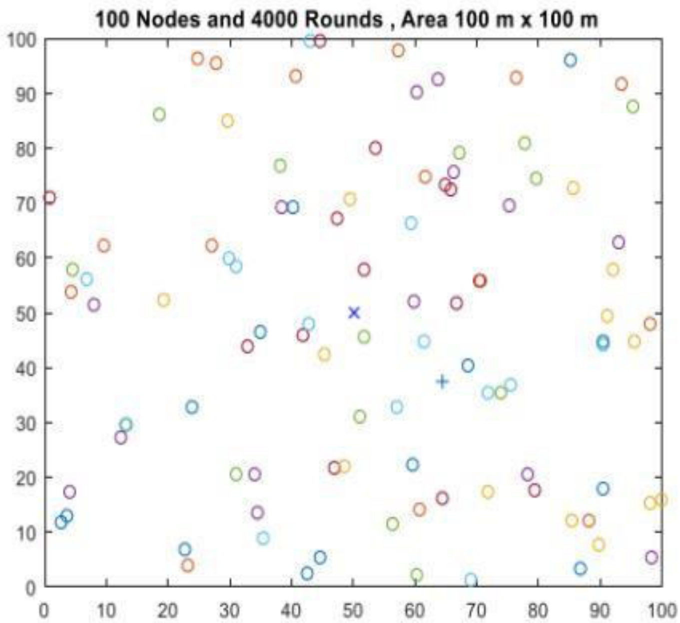

Fig 4: Distribution of node in area of 100m*100m

Moreover, the use of multi hop communication within the clusters has saved energy due to small distance transmissions, however compromised with increased overheads; impacting available bandwidth. The work load is balanced within the network using layered network management; that resulted in increased number of participant alive nodes. At last, the use of collision avoidance and carrier sense multiple access schemes for making propagation between cluster members and cluster data aggregator extends network lifespan while maintaining connectivity for large scale deployment.

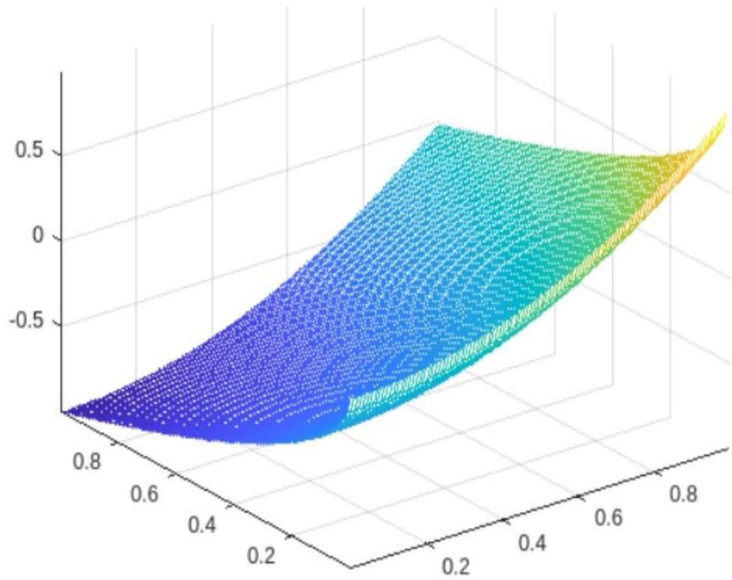

Fig 5: Energy distribution during data propagation

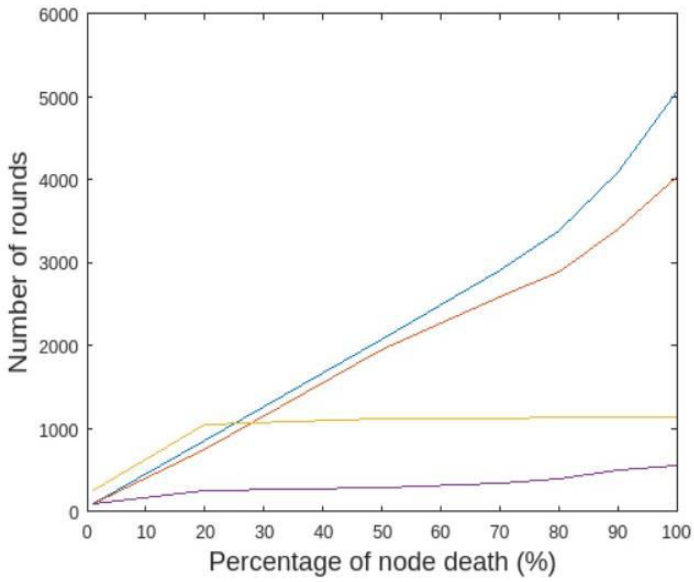

Fig 6: Number of rounds vs percentage of node death by base station

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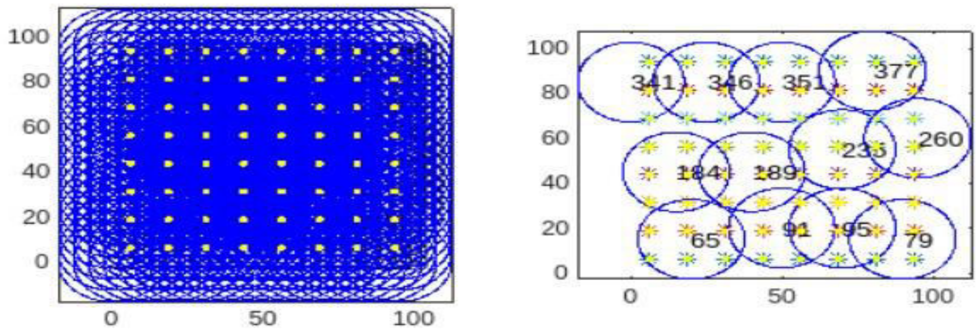

Fig 7: Heat mapping for LEACH

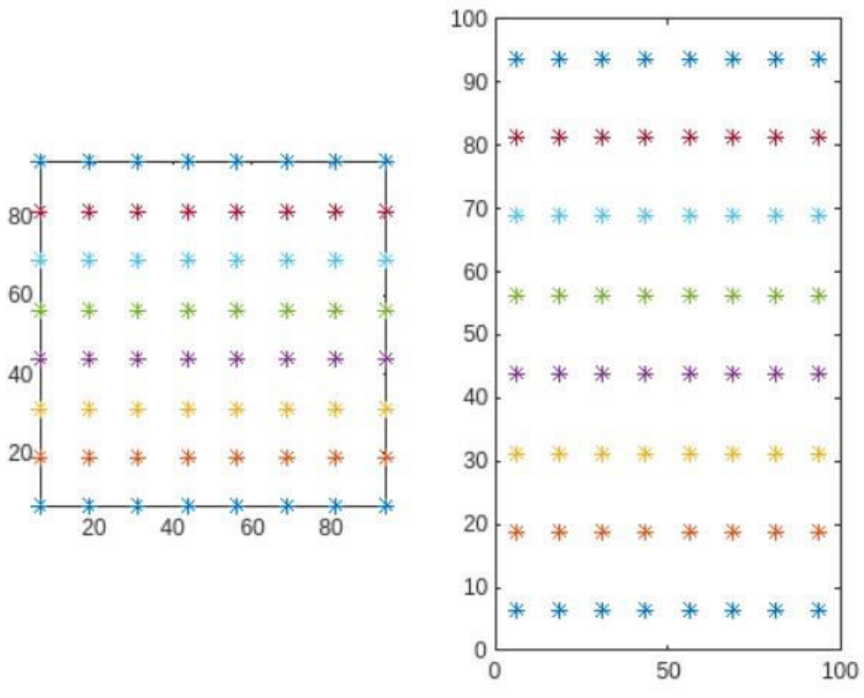

Fig 8: Sensor distribution 100m*100m and Probable Path formation for CH to BS Data Transfer

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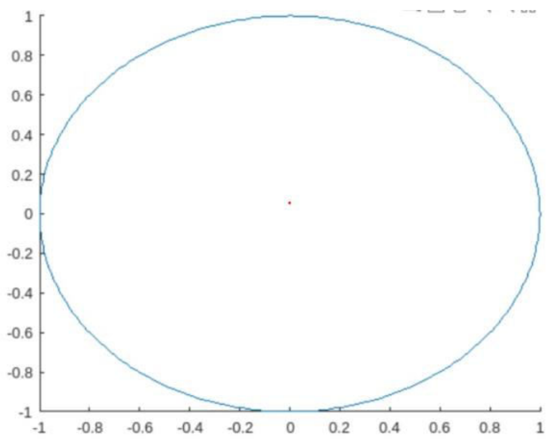

Fig 9: Coverage area of 100m*100m distance circular representation

V. CONCLUSION

In conclusion, the exploration of the Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm within wireless sensor networks (WSNs) underscores its significance in optimizing energy consumption and extending network lifetime. Our comprehensive analysis has delved into LEACH's dynamic clustering, cluster head assignment, and data aggregation mechanisms, emphasizing its ability to distribute energy consumption efficiently. Key metrics, such as energy consumption, network lifetime, and data transmission reliability, have been scrutinized, providing valuable insights into LEACH's performance across diverse WSN deployment scenarios. Comparative analyses with alternative energy optimization algorithms have highlighted LEACH's distinct advantages while acknowledging its limitations. As a feature work, wireless sensor networks (WSNs) could focus on advancing the capabilities of the Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm and its applications. Firstly, efforts should be directed towards refining LEACH's adaptability to diverse environmental conditions and deployment scenarios, ensuring its efficacy across varied settings. Incorporating machine learning techniques to enhance LEACH's ability to dynamically adjust clustering parameters based on real-time environmental changes could significantly improve its performance.

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